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BIOLOGICAL BULLETIN

THE INVERTEBRATE COURSE IN THE MARINE BIOLOGICAL LABORATORY.

A CONTRIBUTION TO THE TECHNIQUE OF TEACHING ZOOLOGY.

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In the thirty-four years of its existence, the course in invertebrate zoölogy, given each summer in the Marine Biological Laboratory at Woods Hole, has undergone considerable evolution. It was founded at the first session of the laboratory in 1888. In the first report of the director, Professor C. O. Whitman, the course is outlined thus:

"The work of instruction, conducted by Professor Van Vleck, was confined chiefly to the study of invertebrate forms, such as the sponges, hydroids, ctenaphors, worms, starfishes, sea urchins, lobsters, corals, etc. An excellent series of mounted preparations added much to the value of instruction. Considerable attention was given to histological technique, and a large amount of valuable material for use in the teaching was collected by each member of the class."

Since that time the course has been in the charge of J. S. Kingsley, specializing in comparative anatomy; H. C. Bumpus, marine zoölogy; James I. Peck, morphology; Ulric Dahlgren, histology; G. A. Drew, biology of molluscs; W. C. Curtis, morphology and regeneration; Caswell Grave, morphology and embryology; and W. C. Allee, ecology and general physiology. Several of these men had served a preliminary term as instructor in the course before taking charge, and this experience made for continuity in its development.

In the earlier years, many of the lectures were given by investigators, not connected with the teaching staff. The whole field of

zoölogy might be considered in this one course, which was designed particularly to meet the need of teachers. In 1893 the work in embryology was taken over in a separate course under the direction of Professor C. O. Whitman, in 1899 Professor Jacques Loeb first offered a special course in comparative physiology, and in 1919 Professor Gary N. Calkins organized the course in protozoölogy; but elementary aspects of these special courses are still retained in the invertebrate course, wherever they are found useful in the study of the subject.

The present type of organization has been in existence since its initiation twenty years ago, in 1901, by Dr. Drew. The conduct of the course as described then by Caswell Grave[1] has seen no radical change, although there has been a gradual evolution away from histological studies towards observations on living animals, in keeping with the zoölogical tendencies of the times.

The instructor in charge of the course bears full responsibility for the selection of the staff, except that the number of staff members is fixed by the laboratory management; there are at present eight instructors and an assistant who acts as preparator and sees to the supply table. The staff is selected from younger instructors or exceptional graduate students and is chosen for teaching as well as research ability, not to mention the physical strength and energy necessary for a long day's teaching and strenuous field trips. An effort is always made to bring these instructors from universities and colleges in different parts of the country in order to have the various types of training represented. The unusual teaching experience is the principal payment for the instructor's labors, although the stipend he receives, together with the accompanying research facilities, is frequently the factor that makes his presence at the laboratory possible.

The work of the staff is divided in open staff meeting with the instructor in charge as chairman, and the general conduct of the course is there discussed and planned. Each member chooses or is assigned some group or groups of animals with which he is especially familiar, or in which he is particularly interested and wishes to work up in the necessary detail. Not only does he

1 "Course of Study in Invertebrate Zoölogy in the Marine Biological Laboratory at Woods Hole," *Journ. App. Microscopy*, 10, 1482–6.

familiarize himself with the forms to be used in the laboratory and with the general literature of the group, but he also spends time studying the representatives found near Woods Hole so as to be able to identify them in the field. He goes through the special literature in order that he may be able to give intelligent information on the points of unusual interest connected with the phylum, particularly the research problems in which it has played or is playing a part.

The instructor in charge of the course determines who shall be admitted to the course under the rules of the laboratory, supervises field work and has general oversight of the organization. He takes his regular turn in lecture and laboratory along with the other instructors. These are in turn individually responsible for the organization and presentation of their particular groups. Each instructor meets with the men who are to assist him, goes over in detail the work planned, and for the time being has complete charge of instruction. He is aided by "experience" cards which set forth in some detail the results of past methods, but he is not bound by tradition.

The course ends on the second Tuesday in August and begins six weeks earlier. This gives a total of thirty-six working days which are divided as follows:

Course lectures, 29.

Special lectures, two by staff members and a varying number of invited lectures from Laboratory investigators.

Laboratory periods, about 56. This number varies with the number of mid-week field trips taken.

Field excursions, about nine.

Holiday, the Fourth of July.

The formal day begins at nine with an hour's lecture, usually on the group to be studied in the laboratory period following. Although it is difficult to generalize about the lecture methods, it is common with the larger phyla to present schematically an ideal representative of a given group, trace its phylogenetic development, describe in detail special structures, or characteristic physiological activities, and give the differentiations within the group and their relation to the environment in which they are found.

Some attention is directed to important principles that are especially well illustrated in that phylum; relatively little time goes to details of classification.

Blackboard drawings, chart and models are employed in the lecture. In general, we find that students will follow a blackboard drawing made before their eyes, with more interest and understanding, in spite of imperfections in execution, than a description illustrated by the most carefully drawn chart. These drawings are diagrammatic and capable of rapid copying by the class, in preference to exact and detailed reproductions.

Supervised laboratory study follows the lecture for two hours in the morning and again from two o'clock till four in the afternoon; normally three instructors are kept busy, though more may be called in on special occasions; as in the examination of plankton. The instructor in charge usually stays on an hour or more later with the students who wish aid in studying their material more fully. The laboratory is open at all hours, and it is unusual to find it empty between six in the morning and eleven at night. Special assistance is given on request whenever an instructor can be reached.

The students who take this work are required to have had at least one year's laboratory work in college biology and to present a recommendation from their college instructor. The class is limited to 55, and in recent years there has always been more than this number of applications. Qualified students from colleges which regularly support the Marine Biological Laboratory are admitted first; after these are served admission depends on priority of application and on training. The class is drawn mostly from institutions over the eastern half of the United States from Maine to Nebraska and from New Orleans to Minnesota. At least thirty colleges are represented by one or more students each summer. A few apply who present only the minimum requirement, but over half of the class has been graduated from college.

Teachers and graduate students are about equal in number among the college graduates. Older people who desire the course as a matter of intellectual curiosity are always present and welcome. Admission is not knowingly granted to students who use the course as a convenience to work off college conditions.

No text is required, although students are advised to keep at hand some standard reference book, such as Parker and Haswell's "Text-book of Zoölogy," or Lang's "Comparative Anatomy." Pratt's "Manual of Common Invertebrate Animals" is constantly used with the field work. Drew's "Laboratory Manual of Invertebrate Zoölogy," which was originally developed for this course, supplemented by additional mimeographed directions, made out by the instructors from year to year, form the guide for the laboratory work. The Laboratory library is open to the students and they are constantly given references to the literature, but they are more interested in studying the animals at first hand and read comparatively little.

Typically, the subject of Invertebrate Zoölogy is divided on this plan:

Protozoa: Two lectures and laboratory days, followed by a morning spent in collecting fresh-water protozoa from neighboring ponds and an afternoon's work in identifying the forms collected. The laboratory is a compromise between the usual type study and a requirement of a certain number of recognizable drawings. In 1920, for example, *Arcella* was studied the first half day; slides mounted a half hour before use showed active movement. *Ameba, Actinophrys,* and *Actinosphærium* were also demonstrated. Almost every one has studied *Paramecium,* but by feeding the animals with hay bacteria stained with neutral red, the student, in the course of watching the feeding activity and the subsequent change of the food vacuole from acid to alkaline, unconsciously reviews many points of former observation, to his considerable advantage. Hypotrichs are always in reserve for this work.

The second morning was occupied with *Euglena* and *Volvox,* with *Ophridium,* a green colonial vorticilid, and the gregarine, *Schizocystis,* from *Phascolosoma,* in reserve. The afternoon was spent on the flagellates parasitic in termites.[1] These form an easily obtainable and fascinating group and it was hard to divert

[1] Leidy, Jos., "Parasites of the Termites," *Jour. Acad. Sci. Phila.,* VIII., pp. 425–447 and plates, 1881. Porter, J. F., *Bull. Mus. Comp. Zoöl.,* XXXIII., 1897. Kofoid and Swezy, Univ. of Calif. Pub. Zoöl., XX., 1919.

the students' attention to *Ephelota* and *Acineta*, the Suctorians found attached to old colonies of *Obelia*.

In the identification of protozoa found in the field, it has been found desirable to ask the student to classify as far as possible; after the order, identification is given or checked by the instructor.

Porifera.—One day, lecture and laboratory. In addition to the more usual study of *Leucosolenia* and *Grantia*, students perform H. V. Wilson's experiment[1] on the dissociation of *Microcione* cells. After squeezing these through miller's bolting cloth, identifying the cells and watching early stages of the plasmodium formation, the slides are put out in a live car under the wharf and taken in for inspection at the end of the course almost six weeks later. Living *Grantia* are sectioned and choanocytes and flagella studied in the normal condition. In order to make this successful the material is not exposed to the air even momentarily until it is sectioned, and then for as short time as possible; the *Grantia* is freshly collected and the razors very sharp.

Cœlenterata.—Four days, lecture and laboratory. In 1919 and 1920 the work on Cœlenterata was begun by starting experiments on regeneration in *Tubularia*. The attention of the class had previously been called to the recent paper of Garcia-Banus and the conflict between that report and the commonly accepted ideas on *Tubularia* regeneration.[2] Data were collected each day under the personal supervision of some staff member who inspected each piece of *Tubularia* and final results were tabulated on the blackboard. The results for 1919 are quoted by Hyman[3] (p. 358) and were supported by the data of 1920 and both confirm the results obtained by Child[4] and Hyman rather than those of Garcia-Banus. Needless to say, class interest in this experiment was intense, particularly among the more advanced students.

The work on the Hydrozoa includes time spent on the structure

1 Wilson, H. V., "Development of Sponges from Dissociated Tissue Cells," *Bull. U. S. Bureau of Fisheries*, 30, 1910.

2 "Is the Theory of Axial Gradient in the Regeneration of *Tubularia* Supported by Facts?" *Jour. Exp. Zoöl.*, 26, pp. 265–275.

3 "The Axial Gradients in Hydrozoa. III. Experiments on the Gradient of *Tubularia*," Biol. Bull., 38, p. 358.

4 "An Analysis of Form Regulation in *Tubularia*," *Arch. f. Entw'lungsmech.*, 24, pp. 1–28.

of *Tubularia* and *Obelia*. These are normally fruiting at the time studied. A morning in which the student sees fruiting *Tubularia* and watches *Actinulæ* emerge and crawl around, added to an afternoon studying *Obelia* which are shedding *Eucope,* makes a day's work that the instructors, at least, never forget. To insure a plentiful supply of *Eucope* or *Actinulæ,* the material is brought into the laboratory a few hours before being studied and allowed to stand in a shallow dish in fresh sea water. The *Eucope* come out more readily if placed in the sun and are to be found on the sunny side of the dish.

Fruiting *Eudendrium, Clava, Hydractinia, Schizotricha* and *Sertularia* are also available for observation and study. In 1921 following a mild winter and an early spring, we could obtain fruiting *Bougainvillia, Campanularia* and *Pennaria. Gonionemus* is studied alive in some detail and living *Physalia* is usually on hand at some time in the six weeks.

In *Hydractinia* the striking *dactylozooids* are readily demonstrated by removing the hermit crab on whose foster shell they grow and stimulating one edge of the colony by scratching with a needle. Under a low-power lens the wave of stimulus can be followed across the colony as the *dactylozooids* strike. These "persons" of the colony are more abundant near the mouth of the shell than elsewhere. In *Gonionemus,* the lithocysts are readily studied by cutting a V-shaped piece from the margin and mounting aboral side up under the high power.

The work on the development of *Aurelia* is on preserved and stained material, although there are usually living *Aurelia* in the laboratory, and sometimes enough of it to supply the class. The canal system is here best demonstrated by injecting it with air, which is easily done even in preserved specimens.

With *Metridium* a half day is spent in repeating Parker's[1] experiments on feeding reactions and an opportunity is given for dissecting recently preserved specmens that have not yet lost all their color. Prepared sections showing relations of the mesenteries are present for special study and living and preserved *Astrangia* is at hand for those who have done the other work. The

1 "The Reactions of *Metridium* to Food and Other Substances," *Bull. Mus. Comp. Zoöl. Harvard,* 29, 1896.

last half of the day of the Cœlenterate group is spent on *Pleurobrachia* which Mr. G. M. Gray preserves in life-like transparency. These are studied in the original preservative, rather than in water.

Platyhelminthes.—Three days, lecture and laboratory. This study begins with locomotion and feeding reactions of fresh-water planaria, and regeneration experiments are started. The animals are kept in pond water. We introduce the class to living *Syncœlidium* or *Bdelloura* from the gill books of *Limulus*. These have lost their pigment and the structure even to flame cells, is visible. Cross sections have been used of late years to give a better demonstration of the relation of the proboscis to other structures. The Cestodes are studied with living *Crossobothrium* when sand shark spiral valves are available; if these are not to be had, *Rhyncobothrium* and *Calliobothrium*[1] from the spiral valve of the dogfish are substituted. Flame cells are readily seen in the scolex of any of these. The encysted scolex of *Otobothrium*[2] found in the muscles along the vertebrae of the butterfish gives an example of the everted pleurocerous stage characteristic of the Tetrabothridia. In 1921 a study of embryonic stages of *Rhyncobothrium* was added to supplement the work on the encysted scolex of *Otobothrium*. The following stages were studied: (1) The freshly laid eggs; (2) eggs in which the hexacanth embryos were developed; (3) emergence of embryos from egg case; (4) free swimming hexacanth embryos with ciliated embryophore; (5) embryo from which the embryophore has been torn off. Directions for obtaining this material as worked out by Dr. Bowen are given in the appendix (1).

A half day is spent on *Tetrastema,* the little nemertean from pilings. These are secured by allowing scrapings taken about 6 A.M. to stand for three hours in fairly deep glass jars filled with sea water; the nemerteans can be picked up with a pipette and a lighted candle held by the jar just below the water level makes them more easily recognized. Scrapings spoil if allowed to stand

1 Linton, E., "Notes on the Entozoa of Marine Fishes of New England," U. S. Comm. of Fish and Fisheries, Comm. Report, 1886 and 1887.

2 Linton, E., "A Cestode Parasite in the Flesh of the Butterfish," *Bull. Bur. of Fisheries,* 26, 1906.

over night. If time permits a half day is also spent on the common rotifers since no other place is available for this neglected group.

Echinoderma.—Four days, lectures and laboratory. At present this work is introduced by a day's study of maturation, fertilization, cleavage and development stages of the starfish egg, with sea-urchin and sand-dollar material in reserve in case of need. Approximate schedules for different stages in the development of *Asterias, Arbacia* and *Echinarachnias,* as worked out by Miss Christianna Smith, are given in the appendix (II.). Preparation for this day's work takes much time and careful cooperation with Mr. Gray in the matter of securing plenty of ripe starfish, since this is near the end of their breeding season.

Work on the adult starfish begins with a study of the activities of the living animal, which includes an annual repetition of Cole's experiments on righting reactions and locomotion;[1] in spite of diffuse lighting and class technique, these have on the whole supported Cole's contention that there is evidence of physiological asymmetry in the starfish. The free cells in the cœlomic fluid are also studied. We obtain these easily by hanging the starfish up by one arm, catching a drop of the fluid as it escapes and examining immediately before aggregation takes place. Circulation in the cœlomic fluid and the dermal branchiæ is demonstrated by means of carmine injection.

The sea-urchin takes more than a day for dissection even though little time is spent on the arrangement of plates in the test. Aristotle's lantern is studied in detail and the genital rachis in *Strongylocentrotus* is dissected. For this work specimens preserved in alcohol are used. The dissection is made by picking off the skeleton in the equatorial region, leaving one ray intact. The exposure is gradually extended to the dorsal region, which is held up as long as desired by the part of the shell still intact. This gives better results than the classical method of dissection.

Ophioderma and *Leptosynapta* are present in reserve for those who have done the regular work. The latter are kept from the

[1] "Experiments on Coördination and Righting in the Starfish," BIOL. BULL., 24, 1913. "Direction of Locomotion in the Starfish," *Jour. Exp. Zoöl.,* 14, 1913.

time they are collected in separate bottles placed in a larger dish of running sea-water to prevent fragmentation. We usually study the swimming motions of *Ophioderma*.[1]

Living representatives of all available echinoderms are kept in aquaria in the center of the laboratory. Some of these contain starfish and mussels and give the starfish an opportunity to demonstrate their feeding methods. *Thyone* are allowed to bury themselves in muck and show their usual feeding reactions and method of respiration.

The last half day is spent on a dissection of narcotized *Thyone*. For this work freshly collected specimens are best. These are injected about an hour before use with about 15 cc. of chloretone solution recently saturated when hot. After a short time the tentacles can be forced out by gentle manipulation and the narcotization holds during the dissection in sea water. It is essential that the chloretone solution should be as strong as possible. There is a great difference between these narcotized animals and the usual formalin faded specimens.

Annelida.—Three days, lecture and laboratory. *Nereis virens* living, preserved, or narcotized in alcoholic sea water, forms the entering wedge for this group. Cleared transverse sections of whole segments are also used to show general relations and especially the parapodia. *Arenicola,* freshly narcotized, are dissected for the blood system and for the nephridia, following directions based on Ashworth's monograph.[2] Sometimes we dissect *Amphitrite* (see appendix III.) and a large collection of other worms is present in the laboratory. Usually *Lepidonotus* is studied for external features, and of recent years a half day has been spent in classifying local annelids, using Pratt's key. Phosphorescence can be successfully demonstrated in *Chætopterus* by taking the animals to the dark room at night, and the class collects swarming *Nereis limbata* when moon and weather permit. The last half day is normally spent in a dissection of the common sipunculid, *Phascolosoma,* freshly narcotized in alcoholic sea water.

[1] Grave, Caswell, "*Ophiura* (*Ophioderma*) *brevispina*," Mem. Biol. Lab. Johns Hopkins Univ., 4, 1900.

[2] Ashworth, J. H., Liverpool Marine Biology Committee Memoirs, XI., 1904.

This laboratory work has sometimes been introduced by a study of the 48-hour *Hydroides* trochophores. The primitive structures can be easily made out. These are followed by 5–7 day larvæ showing the greater development of the tail region.

Bryozoa.—One day, lecture and laboratory. Living *Bugula* furnishes the main attraction, and some time is spent on the encrusting forms.

Crustacea.—Three days, lecture and laboratory. The treatment of this phylum has undergone more changes than that of any other group in my eight years on the course. At one time a week was spent in detailed study of their homologies.

We give one afternoon of the three days now allotted them to studying tow, which contains a large number of larval crustacean stages at this season of the year, but is examined for other animals as well.

The lobster is the introductory animal, with the blue crab as alternate for those who have already dissected the lobster or the crayfish carefully. These are injected and hardened (see appendix IV.) in formalin for two weeks before using. One day is given to this dissection, with an extension of time for those who need it. More time could well be spent here but it is better used elsewhere in this crowded course. Some study is made of the usual Entomostraca, such as *Cyclops* and *Argulus* and a half day is spent in working out appendages of Malacostracan forms, which are recorded as shown in appendix V. While on the chart rack the information given in appendix VI. is displayed to aid the students in making comparisons readily among the forms studied.

The work is finished by a half day spent in dissecting *Lepas* with *Balanus* present for comparisons. Among the interesting side lights that have been presented from time to time the following have been especially successful:

Argulus placed in finger bowls with *Fundulus* attach themselves to the fish and change color as the *Fundulus* change from being placed on different backgrounds. This is difficult because of the time required to accumulate enough *Argulus*.

Blood coagulation is shown in *Oniscus* by snipping off the filamentous tip of the antennæ. A drop of blood is caught on the

coverslip and by staining in methyl green or aqueous iodine, a cell-agglutinating type of blood-clotting may be observed.[1]

Autotomy is usually demonstrated in *Uca*, the fiddler crab, by crushing the distal end of one or more of the legs with a pair of forceps. Chromatophore activity is well shown in *Palæmonetes*.

Limulus.—One day, lecture and laboratory. We formerly gave a half day to the external anatomy of *Limulus*, using small specimens. At present in addition to the time on the external anatomy and feeding experiments, a half day that usually stretches well on into the night is spent in dissection. *Limulus* is particularly interesting to us as a persistent type, because of its use in phylogenetic theory and because it is a characteristic and common large invertebrate of Woods Hole. The dissection directions have been worked out in the main by Dr. R. H. Bowen and are given in full as Appendix VII, since I know of no other directions in print.

Mollusca.—Five days laboratory, four lectures. This group is introduced by work on *Chætopleura*, which may be mounted on glass slides if put under water, and may then be readily studied on both dorsal and ventral sides. The principal study of the group centers about *Venus* (or *Unio*), *Busycon* and *Loligo*. Usually one instructor is in charge of the earlier part of the work and another has the Cephalopoda.

In the Pelecypoda, comparative studies are made of *Pecten*, *Mytilus*, *Mya*, *Ensis* and *Ostrea*, with a drawing of one form; and living and preserved slides are studied in *Venus*, *Mytilus* and *Ostrea*. The gill current can best be seen in the latter on account of the large large size of the palps on which ciliary currents can be seen. In the opening dissection, the blood system shows much better if injected through the ventricles.

The work in this group also includes study in locomotion of *Ensis*, *Yoldia*, and *Solemya*, and egg laying, fertilization and cleavage in *Cumingia*.

The gasteropod work is limited to *Busycon* (*Sycotypus*, *Fulgur*). These are killed and injected a week before using in order that they may be hardened sufficiently to get rid of slime

[1] Tait, *Jour. Mar. Biol. Assn.*, 1911.

without being too hard for satisfactory dissection. One and a half days should be spent on this dissection, although the familiar device of allowing half the class to work out and demonstrate the circulatory system while the others reciprocate with the nervous system, disposes of the dissection in a day.

Cephalopod study is limited to the common squid, *Loligo.* Living specimens are in the students' aquaria and in the central tanks through the week; egg laying frequently occurs. The most spectacular demonstration of the course comes when the living squid are injected through the buccal sinus for venous system and through the heart for arterial, and studied immediately in salt water. Almost the whole system can be made out without cutting. The better prepared students make the complete dissection of the spermatophoric organ, for which directions are found in the third additon of Drew's Manual. It is obvious that in this work, as on *Busycon,* there is not time for finished dissections and drawings, but it is surprising how much good work can be done in the concentrated effort of a long day, especially if drawings of external features be largely omitted.

Chordata.—Two days, lecture and laboratory. Chordate studies are limited to the Hemi- and Urochordata. The work begins with a study of external features of *Dolichoglossus.* These may be collected Saturday afternoon and kept until Monday in good condition if placed in separate bottles over which a good supply of water flows. The remainder of the first day is spent largely on *Molgula,* living and preserved.

Perophora is used to demonstrate the circultion and the modification found in a stolon type. Young *Botryllus,* that are still transparent, are also present in the laboratory in reserve. *Amaræcium* tadpoles, alive and stained, take up the last morning of the course. The last afternoon is spent in working out some form, such as the adult *Amaræcium,* with no help other than that to be found in texts and laboratory guides. The exercise is not an examination; it counts no more in our estimation of the ability of students than that done on any other half day. It gives the student an opportunity to orient himself under conditions less favorable to rapid work than those that prevailed in the preceding

part of the course; and it holds the attention of the class completely even past the official end of laboratory work.

No attempt is made to put the entire class through a fixed schedule of laboratory work; even where everyone is working on the same material, as much as possible of the method of attack and particularly of the method of recording observations is left to the individual. Students who desire space in the laboratory and access to laboratory material but who have their own plan of work they desire to follow, are welcome as a matter of course.

Field Work.—The field work is one of the most important aspects of the entire course; even the anatomy cannot be clearly understood until the animal has been seen in its native haunts. Gross collecting methods are avoided as far as possible and the student is urged to observe carefully while collecting where the animals are found and what they are doing.

The field schedule for 1921 follows:

July 2, Saturday:
  Collecting Protozoa 10:00–12:30.
  Examination of material in laboratory, 2:00–4:00.

July 6, Wednesday:
  Crane's Wharf. Start 2:00; low tide, 3:20; return about 4:00.

July 9, Saturday:
  Vineyard Haven Wharf. Start 8:45; low tide 3:20; return about 2:00.
  Examination of collection in laboratory, 2:00–3:00.

July 16, Saturday:
  Hadley Harbor (Northeast Gutter Flats). Start 10:00; low tide 11:55; return about 3:30.

July 20, Wednesday:
  Hadley Harbor (Gutter Rocks). Start 1:45; low tide, 2:23; return about 4:15.

July 23, Saturday:
  Dredging, Vineyard Sound.
  Section 1, teams 1–4 start 10:00; return about 12:00.
  Section 2, teams 5–8 start 2:00; return about 4:00.

July 28, Thursday:
  Study of "Tow" in laboratory, 2:00–4:00.

July 30, Saturday:

North Falmouth Flats. Start 8:45; low tide, 9:35; return about 3:00.

August 4, Thursday:

Kettle Cove, Rocks and Flats. Start 1:45; low tide, 2:33; return about 5:00.

August 6, Saturday:

Picnic. (1921, Penikese.)

Practically the same field organization has been used for the last eight years. The class is divided into as many teams as there are instructors; the team has the same members throughout the course, but the instructors rotate so that each team has the benefit of three different instructors in the field. In each team one student is recorder for the day; others have various assignments depending on the trip. If this be to a flat, two have shovels, one a bucket and crystallization dish, one a *Cumingia* sieve, and the rest carry collecting kits with bottles and jars, forceps and lenses. All are mentally and physically prepared to get wet and dirty.

The Protozoa field trip follows the Protozoa work in the laboratory. While the class is studying Cœlenterates and sponges, two trips are made to wharf piles. Collecting is done from small boats, and glass-bottomed buckets and scrape nets are an important part of the equipment. The trips to flats and rock gutters, and the dredging both depend for their sequence on the tides. It is a general rule never to take a trip in the morning and attempt regular class work in the afternoon. We have found that the students are too tired or diverted to settle down to class dissection. They are interested in working over the specimens collected on the trip and this informal study has become more common of recent years.

At the beginning of the course the student is supplied with a check list of the animals taken by the class in the last ten years. It is suggested but not required, that these be made the basis of class records of experience for the season, so that the student obtains a permanent record of the habitat distribution found by the class collecting that year.

The recorders are furnished with a board bearing a list of the

animals expected from the habitats in the locality to be studied. This is arranged so that an animal may readily be recorded from all the habitats in which it may be found. So far as possible the instructor attempts to teach the students in the field classification down to genus. Species identification is given the student only when of special interest or, in the case of the *Nassas* and *Littorinis,* necessary. The instructor calls attention to interesting facts in the distribution, and other points calculated to make the student more familiar with the animal under consideration. Each instructor is supposed to have a wide knowledge of the group on which he lectures, and doubtful specimens are referred to him for identification. Animals that cannot be named in the field go into the "question mark" bottle for later reference.

On returning to the laboratory a complete list of all the animals found by the class is posted on the board. The list in Appendix VIII. gives the result of one day's find on the North Falmouth Flats in 1920. The list is entirely typical and shorter than the lists frequently reported. No one team found all of these; the individual teams listed from 50 to 96 species, depending on the ability of the team members, the experience of the instructor and the run of collecting luck. It is on record that twice teams have collected and their instructor identified more than a hundred species in one afternoon; but usually there is no effort made to obtain mere numbers of forms. The emphasis is rather on the characteristic animals in the different habitats studied.

While students may make collections and spend considerable time over detailed classification if they desire to do so, they are not urged in this direction. Neither is there any attempt to have students write up accounts of the field trips; even the keeping of records of the animals found is optional. This is in keeping with the general policy of instruction, that as much as possible must be left to the initiative of the student. Each year there are a few students with especial interest in field studies who devote extra time to them; but it is surprising how well the average student learns to recognize and name characteristic animals with no insistence on the part of his instructors.

After one of the early trips all animals taken are demonstrated

in separate finger bowls in order that a named collection of living animals be at hand for closer inspection than is possible in the field; later only the rarer animals are demonstrated. The course possesses a named collection of the common molluscs of the region and is accumulating preserved collections of other groups.

With the exception of the afternoons on Plankton and Protozoa, little attempt is made to identify for class purposes the nearly microscopic animals that may be taken, since it is the purpose of the trips to acquaint the students with the larger, more outstanding members of the local fauna. Doubtless we pass over more species than are recorded. The field collecting has given a number of new records for this well-worked region, has yielded material for one study of regional and seasonal distribution,[1] and is the basis for a study of the littoral ecology of Woods Hole now in preparation.

In earlier days and again for the last eight years a catalogue record of species taken has been kept and is on record as a part of the library of the Laboratory. The person in charge of this compilation is frequently called on to suggest to investigators available material suitable for certain investigations, or the whereabouts of animals not usually collected by the supply department.

Near the end of the course the field work is summarized in an evening lecture on the ecology of the region, illustrated by slides obtained from the American Museum of Natural History and by projections of living animals.

The students have the advantage of the bi-weekly evening lectures maintained by the Laboratory; in addition, special lectures directly related to the work of the course are arranged for the benefit of the class. These are usually given on Saturday morning before the field trip for the day, or in the evening, and they not only convey the information, but introduce the class to some of the interesting personalities among the research group. In 1920 these special lectures were given:

"Some Aspects of Physical Organization of Protoplasm," by Robert Chambers.

[1] Allee, W. C., "Note on Animal Distribution Following a Hard Winter," Biol. Bull., 36, pp. 96–104.

"Observations on Egg-laying in the Trematode, *Epobdella*," by Edwin Linton.
"The Elementary Nervous System," by G. H. Parker.
"Metamorphosis in the Echinoderms," by Caswell Grave.
"Zoölogical Research," by C. E. McClung.

The Laboratory gives no credit for work done in its courses, nor does it keep formal record books. A student so desiring may receive a certificate stating that the work of the course has been satisfactorily completed and may then cash this in at his college for undergraduate, and in most institutions, for graduate credit (*e.g.*, Chicago, Wisconsin, Cornell). All colleges do not allow the same amount of credit; the usual practice is to give from 5 to 6 semester hours' credit for the work of the course. Any student may have his laboratory notes inspected by the instructor in charge of the group, and all persons asking for certificates must submit their notes for such inspection.

The course outlined is sufficiently different from the ordinary college course, both in its method of presentation and its effect upon students, to arouse constant curiosity as to its essential points of variation. At Woods Hole there are unusual temptations to sight-seeing, boating and bathing, but the attitude of the class is anything but the summer-vacation type that prevails in many summer schools.

The great efficiency and speed attained and held by the class through the six weeks must be ascribed in some degree to the presence of three trained teachers, the instructor in charge and the two assisting members of the staff, who are always at hand in the laboratory when needed; though they give as little oral instruction as possible, so that the student is a more independent worker at the end of the course than he was at the beginning.

I am inclined to think that the intensive work which the students accomplish is due in part to the very speed with which ground is covered. It appeals to the imagination of the student to look back at the end of ten days over the Protozoa, the sponges and cœlenterates, with three field trips extra. Further, he has the advantage of no other study to distract his mind. Through the winter his attention must ordinarily be stretched over three

to six diverse subjects; these six weeks at Woods Hole belong to zoölogy alone.

He has before him the constantly shifting panorama of the animal kingdom, and each animal group is presented by a new instructor with a fresh point of view and a different method of procedure. It is an interesting sight to watch the class when fagged near the end of the course, rise to the stimulus presented by an instructor with a new way of looking at things in general and this especial group of animals in particular.

Another potent cause for sustained interest is the excellent supply of living or recently preserved animals which Mr. Gray, of the supply department, keeps in the laboratory. Up to the limit of his working ability, the student will not let this material go to waste.

The intercollegiate character of the class personnel gives stimulus to high-grade work. If undergraduate, the students are usually the pick of the department sending them; if graduate students, they are at least serious-minded. Many of them feel that they are personal representatives of their college and more especially of their home department of zoölogy and they take pride in bringing credit to their training.

Finally, there is not the usual reserve between instructors and instructed. To a great extent the general attitude is that of two groups of people, both recognizing that they are fellow-seekers after information, but one, due to greater experience, obliged to confess complete ignorance less frequently than the other group. Even if he desire to do so, the instructor cannot keep a dogmatic attitude in the face of eight students digging all sorts of animals from the sand and mud and asking questions which a dozen specialists could not truthfully answer without an occasional "I don't know."

From my observation of the effects of this scheme of class work in the Woods Hole course, I believe the following aspects could be carried over with profit into the usual winter zoölogical courses.

1. The introduction of more work with living animals, particularly in the introductory course, and the elimination of much

of the work on formalin specimens. This has been done in the Michigan course as outlined by Shull and his associates, and I believe that the method is applicable in the majority of our laboratories. This requires more work in the presentation of a course, since it is easier as well as cheaper to buy, for example, formalin-preserved earthworms than to keep living ones ready for study at the desired time. It necessitates also an acquaintance with the local animals and their peculiarities of structure and habit, when these are not described in the standard textbooks.

2. Aquaria with living animals should be constantly in the laboratories of appropriate classes even though no work is assigned to be done on them. They will interest our better students in spite of themselves, even in the midst of the crowded winter curricula and outside activities. These aquaria may well include a balanced salt water one.[1]

3. Wherever possible, field work should be included with the work in the first-year course, since it is impossible to understand even the morphology of an animal when seen only in the pickle jar and laboratory environment. Students should not be taken out *en masse,* but in carefully divided groups and the trip should yield definite information which the student will recognize as being an integral part of the course. One section of the year's work in the elementary course, preferably the spring, may well be devoted to field studies which should serve to emphasize many of the problems discussed earlier in the year.

4. A number of approximately equally well-trained instructors should be associated in giving the larger courses. I regard the results from the staff here described as definite proof of the inferiority of the usual method whereby one man, in charge of the course, gives all the lectures and others, poorly trained, often be-

[1] Salt water may be obtained from the sea shore and inexpensively shipped by freight half way across the continent. Living animals for salt water aquaria, together with plants to balance them, may be secured from Mr. G. M. Gray, of the M. B. L. Supply Department. For best results this material should be forwarded soon after definitely cool weather sets in. Mr. Gray always sends more animals than can well be kept and the hardest task is to kill enough at the beginning so that the others may have a fair chance to live. I have kept such an aquarium running for seven months with no trouble other than keeping the water level constant by adding distilled water.

ginning graduate or advanced undergraduate students, give laboratory instruction. I understand the conditions under which this type of instruction has arisen but it is essentially unsound.

The lectures frequently become a routine re-hashing of bygone compilations on phases of the subject of no particular interest to the lecturer, and often quite unrelated to the laboratory work. This is not true in the fortunate laboratories where the lecturer in the large classes is a brilliant master of his subject matter, the English language and the principles of pedagogy, but it holds for too many courses. It is true that a certain coherence of presentation is gained when all of the subject matter passes through one mind, but personal prejudices are likewise transmitted, however unconsciously. Effective teaching is done only when the student is keenly interested and the shifting of lecturers makes naturally for a stimulus of interest.

In the laboratory work, the advantage of the employment of a group of men all well grounded in the essentials of the subject is obvious. The odd findings of an enterprising student can be capitalized, explained on the spot or their source of explanation suggested, when in the ordinary routine of laboratory work such unknowns must of necessity be disregarded by the undertrained or overworked teacher. I am thoroughly convinced that very seldom should instruction be given in college or university by persons under the rank of instructor, with its present connotations, and that courses should be limited or teaching staffs increased until this is possible.

5. The dominant spirit at Woods Hole is research or preparation for research, and this atmosphere does much to color the work of the Invertebrate Course. I am not yet convinced that teaching of undergraduate students stimulates research, or that an instructor who allows himself to be submerged in research should be trusted in an elementary course; but I am certain that, other conditions being equal, the best teaching is done by men actively engaged in some form of research and in a laboratory where the research purpose prevails.

APPENDIX.

In this appendix are given some more technical directions that we have worked out and that are not readily available lesewhere.

I.

Embryology of Rhynchobothrium: Dr. R. H. Bowen.

Take from the spiral valve of the dogfish the ripe, free, milk-white proglottids of *Rhynchobothrium* and place them in finger bowls of fresh sea water; ten or a dozen may be put in one bowl. Care should be taken not to carry over too much of the digestive slime as it is not feasible to change the water once the eggs are laid. If the proglottids are ripe they discharge the eggs at once in a white cloud. The empty proglottids should be removed and the finger bowl set aside without agitating the water. The eggs soon become dark brown or blackish and stick together and to the bottom of the dish in a solid mass. By keeping the eggs thus bunched their concentration can be controlled when removing them for study. Fresh eggs can be examined at once after laying, but they offer nothing of special interest. After not less than three days and up to periods of five to six days, the hexacanth embryos are completed and ready to emerge from the egg cases. Remove a part of the cluster of eggs by scraping them off and sucking up in a pipette and examine under the microscope. The mechanical disturbance of moving them seems to stimulate the embryos, for it is usually easy to find a number of embryos just emerging from the egg-cases; also free swimming embryos and empty egg-cases. Cultures four days old are generally the best.

II.

Approximate Schedule for Stages in Echinoderm Development Under Mid-July Conditions, from the Experience of Miss Christianna Smith.

1. *Asterias forbesi.*

Stages.	Time after Fertilization.
Polar body formation	45–60 minutes.
Two celled	2–3 hours.
Four to eight celled	3–4 hours.
Sixteen celled	4–5 hours.
Late blastula	7–10 hours.
Early gastrula	18–21 hours.
Late gastrula	24–30 hours.

2. *Arbacia punctulata.*

Two celled	1 hr., 30 minutes.
Four celled	2 hrs., 30 minutes.
Eight celled	2 hrs., 45 minutes.
Sixteen celled	3 hrs., 45 minutes.
Sixty-four celled	4 hrs., 15 minutes.
Early blastula	7 hrs., 15 minutes.
Late blastula	14 hours.
Early gastrula	23 hrs., 30 minutes.
Pluteus	Two days.

3. *Echinarachnius parma.*

Two celled	1 hr., 35 minutes.
Four celled	2 hrs., 45 minutes.
Sixteen celled	3 hrs., 15 minutes.
Sixty-four celled	4 hrs., 15 minutes.
Early blastula	6 hrs., 15 minutes.
Late blastula	10 hours.
Early gastrula	21 hours.
Late gastrula	38 hours.
Pluteus	Two days.

III.

Dissection of Amphitrite ornata: Dr. E. F. Adolph.

From a doped or freshly killed specimen obtain some of the cœlomic fluid by making a small slit in the body wall. What is the color and consistency of this fluid? Examine under the microscope and observe the varieties of cells present and their movements. Some of them are reproductive products.

Pin down the specimen, either fresh or preserved, under sea water with the dorsal or bristle-bearing surface upward. With the scissors cut along the mid-dorsal line, piercing only the body wall. Pin the body wall out flat as you cut from head to tail.

Cœlom.—Are there transverse septa or diaphragms? Note the dorsal and ventral mesenteric strands which hold the digestive organs in place. Cut the dorsal ones. How do the details of internal segmental organization correspond to the external organization?

Circulatory System.—This must be observed before further dissection. Find the large, paired, sub-intestinal vessels. Trace them backward as far as you can and forward into the single gas-

tric vessel which continues into the dorsally situated heart. From the heart the branchial vessels go forward to the three pairs of gills. Find the ventral vessel and note its transverse branches, some of which encircle the digestive organs. You may be able to see also the dorsal, neural, lateral and esophageal vessels, all longitudinal.

Digestive System.—Is the mouth ventral or dorsal? It leads into the straight muscular esophagus. How is the latter held in place? Is there a protrusible pharynx? The esophagus opens into the wide straight stomach. Does it show any segmentation? The winding portion of the alimentary tract is the intestine which continues to the anus. Cut open the stomach and note the character of its walls.

Muscles.—Find the transverse-oblique, longitudinal, setal, and circular muscles. Make a rough diagram of the animal through the stomach region, showing the relative positions of the muscles, stomach, and blood vessels.

Nephridia.—Cut through the oblique muscles in anterior somites and expose the nephridia. Quickly sketch the natural position and shape of one of them. How many external openings or nephridiopores do you find? Put a nephridium from a freshly killed worm under the microscope. How do you think the nephridium functions in the living body? The gonadal glands are small white glands ventral to the esophagus. Ventral to them are the larger and yellowish "stomach glands." The nephridia may serve as gonoducts.

Nervous System.—Displace the digestive organs to one side and find the ventral nerve cord. Has it ganglia? Can you find paired transverse branches? What features of the nervous system are metameric? How far does the ventral nerve cord go posteriorly? Anteriorly try to find the sub-esophageal ganglion, the circum-esophageal connectives and the supra-esophageal ganglion. Where would you expect to find sense organs in *Amphitrite?*

Make a list of the special features of the anatomy in *Amphitrite* that are especially significant in view of its habit of living. Compare the anatomy with that of *Nereis.* Which of the two species

do you consider to be the more highly differentiated? Which is better fitted for self-maintainance and self-preservation? Make a table of the functions performed by the body of *Amphitrite* under two headings; those without which the animal or species could not survive, and those which are luxuries. Are any of these functions performed in a way which you consider more efficient by animals you have already studied in this course?

IV.

Injection of Blue Crab (Callinectes sapidus).

The location of incision to reach the heart is shown in Fig. 1. The injecting syringe should be inserted in horizontal position.

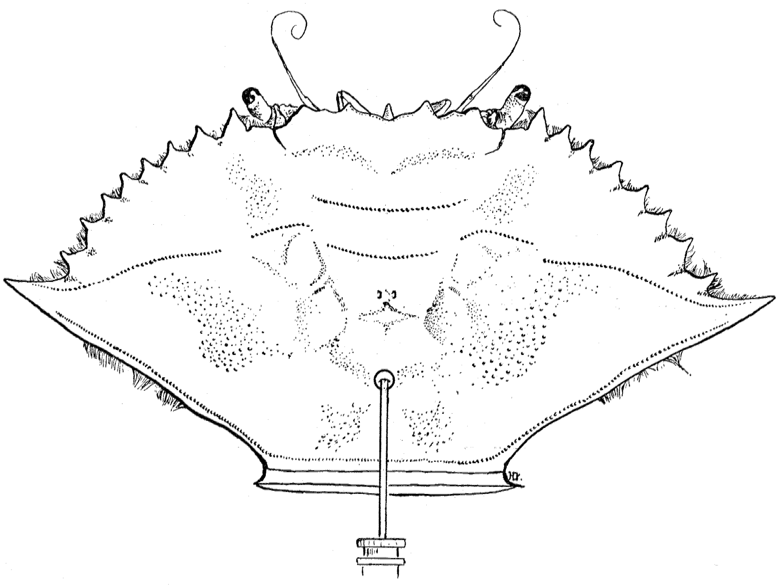

Fig. 1. Dorsal view of the blue crab, showing method of injecting through the heart. Drawn from an injected specimen by Helen Daniels Young.

V.

Table I.

A Comparative Study of Appendages of Common Woods Hole Crustaceans.[1]
Reworked with aid of Mr. J. P. Visscher and Dr. J. A. Dawson from a table made by Dr. G. S. Dodds.

	Lobster.	Blue Crab.	Hermit Crab.	*Hippa.*	*Mysis.*
0	Stalked eye	Stalked eye	Stalked eye	Long stalk	Stalked eye
1	Antennule	Do. small	Do. Short, single	Do. Small, 2 flagella	Antennule
2	Antenna	Do. small	As lobster	Coiled under mouth parts	Antenna large exopod
3	Mandible Palp 3 seg.	As lobster	As lobster	Mandible soft	Mandible small
4	1st Maxilla No endopod	Do. biramous	As lobster	As lobster	1st Max. small
5	2d Maxilla Scaphognathite	As lobster	As lobster	As lobster	2d Maxilla Biram. plumose
6	1st maxilliped biramous, endopod with 2 joints	As lobster	As lobster endopod unjointed	1st maxilliped	Biramous leg
7	2d maxilliped biramous, endopod with 4 joints	As lobster	As lobster	As lobster folded	Biramous leg
8	3d maxilliped biramous, endopod with 5 joints	As lobster flattened	As lobster	3d maxilliped operculate	Biramous leg
9	Large chela	As lobster	As lobster	Digger uniramous	Biramous leg
10	Chelate leg	Non-chelate leg	Do.	Digger uniramous	Biramous leg
11	Chelate leg	Non-chelate leg	Do.	Digger uniramous	Biramous leg
12	Non-chelate leg	Non-chelate leg	Reduced	Digger uniramous	Smaller leg
13	Non-chelate leg	Swimming leg	Leg small	Long, folded	Brood sac from base in female
14	♂ Small modif. ♀ Biram. small	♂ Modified ♀ Biramous	o or left only	♂ o ♀ Small	Swimmeret small
15	Swimmeret ♂ Slightly modif.	♂ Modified ♀ Biram.	Small, left only	♂ Uniram. ♀ Small	Swimmeret small
16	Swimmeret	♂ o ♀ Biram.	Small, left only	♂ o ♀ Small	Swimmeret small
17	Swimmeret	♂ o ♀ Biramous	Small, left only	o	Swimmeret
18	Swimmeret	o	o	o	Swimmeret
19	Uropod Biramous	o	Uropod hooks, left larger	Biramous	Uropod long Lithocyst
20	Telson large	Telson small, pointed	Telson hooked	Do. long, pointed	Do. long, flat

All these have fused cephalothorax.

[1] Tables I. and II. are inserted, although not prepared for publication, because so many teachers of experience have spent time in copying them when given the opportunity.

	Talorchestia.	*Caprella.*	*Oniscus.*	*Argulus.*
0	Non-stalked eyes	Do.	Do.	3 non-stalked eyes
1	Uniramous, short 1st antenna	Do. long	Rudimentary	Minute, 4 segments
2	Uniramous, 2d antenna. ♂ long, ♀ short	Shorter	Well developed	Small
3	Mandible, chitinous teeth and palp	Minute	Mandible	3 and 4 fused in proboscis to form piercing mouth parts
4	1st Maxilla biram. small	Minute	1st Maxilla	
5	2d Maxilla biram. small	Minute	2d Maxilla	Slender
6	1st Maxilliped fused, 2 lobed lower lip	Small	Maxilliped	o
7	Small uniramous hooked	Sub-chelate	1st leg	Suckers
8	Sub-chelate, large in male	Do.	2d leg	Leg-like
9	Uniramous leg	Gill, Brood pouch in female	3d leg	Large leg
10	Uniramous leg	Gill, Brood pouch in female	4th leg	Large leg
11	Uniramous leg pointing backwards	Leg	5th leg	Large leg
12	Uniramous leg pointing backwards	Leg	6th leg	Large leg
13	Uniramous leg pointing backwards	Leg	7th leg	o
14	Swimmeret	Abd. rudimentary	Slender endop. gill exopod, operculum	Unsegmented
15	Swimmeret	Abd. rudimentary	Slender	Unsegmented
16	Swimmeret	Abd. rudimentary	Slender	Unsegmented
17	Jumper large biramous	Abd. rudimentary	Slender	Unsegmented
18	Jumper large biramous	Abd. rudimentary	Slender	Unsegmented
19	Jumper large biramous	Abd. rudimentary	Biramous feelers	Unsegmented
20	———	———	———	———

Fusion

	1st thoracic fused to head	1st and 2d thoracic fused to head	1st thoracic fused to head	3 free thoracic segments

VI.

TABLE II.

COMPARATIVE MORPHOLOGY AND PHYSIOLOGY OF DIFFERENT GROUPS OF CRUSTACEA. Compiled by Dr. Raymond Binford.

	BRANCHIOPODA	OSTRACODA	COPEPODA	CIRRIPEDIA	MALACOSTRACA
Body Segments	Vary, 13-42. Abdomen no appendages. Apus 50 " " on 17 segments.	Indistinct. No limbs on posterior part.	16. Antennules, antennae mandibles, 2 maxillae, 1 maxilliped = 6. 5 with biramous app. 5 abdominal	Indistinct. No abdomen	19. 8 thoracic. 6 abdominal.
Carapace	None, shield or bivalve, attached to only a few segments in front.	Bivalve.	Absent or reduced.	Mantle of several plates Bivalve-shell in larva	Variable. Covers cephalothorax in many.
Tail	Usually a caudal furca	Caudal furca.	Caudal furca.	Caudal furca in most forms.	Telson. Caudal furca in very few.
Eyes	Paired, compound. Nauplius eye usually present.	Compound in a few-Myodocopa. Nauplius-eye present in most.	Nauplius-eye No compound eye.	Nauplius-eye on dorsal surface of stomach	Compound on movable stalks.
Antennules	Small, unsegmented, sensory. Clasping organs in some ♂-Cladocera.	Large. Sensory or locomotory. 8 segments. Some less.	Uniramous. 25 segments with exceptions. Swimming or clasping organs	Used for attachment.	Bears 2 flagella.
Antennae	Anostraca claspers. Notostraca absent or vestigial. Concostraca, Cladocera swimming organs.	Large. Chiefly locomotory. Bears spinning gland in Cytheridae.	Usually biramous, swimming organs.	Disappear in adult.	Scale for exopodite in most.
Mandibles	No palp.	Palp large. Labrum. Clasping organ in Sarsiella.	Sometimes keeps biramous structure in adult	Palp rudimentary.	Lacinia mobilis often present.
Maxillae	1st small, lobed. 2nd mostly small. In Cladocera absent	Absent or variously modified.	Present. 2nd sometimes clinging organs	1st present. 2nd united in lower lip.	Both maxillae present
Appendages	Foliaceous. Respiratory bract.	4 or less back of mandibles. Leaf-like or leg-like. Posterior leg-like.	1 uniramous maxilliped Clinging in some. 5 pairs biramous legs.	6 biramous pairs.	Thoracic & abdominal present & distinct
Locomotion	Swimming by foliaceous appendages. Conchostraca, Cladocera by antennae.	Antennae. A few by antennules.	Antennules, antennae & thoracic appendages	Adults sessile.	Flexible abdomen, tail fin walking legs, swimmerettes
Capturing Food	By gnathobases of appendages.	Large mandibles and labrum.	Mandibles. 2nd maxillae.	Thoracic appendages.	Prehensile legs, several mouth parts.
Excretion	Maxillary gland. Larvae have antennal gland.	Glands at bases of ambulatory legs in some. Cypris antennal & maxill. glands	Maxillary gland.	Maxillary glands.	Antennal glands more common.
Reproduction	Sexes separate. No spermatophores. Most sperms spherical. Development in uterus or brood pouch. Nauplius.	Sperms filiform. Some spherical. No spermatophores. Eggs develop in shell, on plants or free in water. Modified nauplius	Spermatophores. Eggs in packets attached at opening of oviduct. Nauplius.	Hermaphrodite. Sperms filiform. Development in mantle cavity. Nauplius with few exceptions.	♀ apertures 6th, ♂ on 8th thoracic segment. Spermatophores.

VII.

Laboratory Work on Limulus: Dr. R. H. Bowen, Dr. C. L. Parmenter and Mr. D. B. Young.

In addition to the work outlined in Drew's manual, the following studies can be readily and satisfactorily made:

I. *Method of Feeding.*—Place a large *Limulus* on its back and wait until it is perfectly quiet. Then place bits of mussel, drops of fluid from a macerated mussel, and bits of *Nereis* on the spiny bases of the legs and note the rôle played by each appendage.

II. *Dissection.*—A longitudinal section of *Limulus* cut just a little to one side of the median plane shows that the various organ systems are arranged in layers. Suspended from the dorsal carapace is the tubular heart surrounded by the pericardium. Below the heart is the digestive tract. This consists of the esophagus, a tube which leads forward to the stomach or proventriculus, which turns upward and backward and opens into the straight intestine. At the junction of the esophagus and proventriculus is a plate of skeletal material, the endocranium, which continues back through the cephalothorax. Below this internal support is the central nervous system. Such a dissection, although useful, does not show the various organs as well as does a dorsal view. Therefore the following method is advised. Students will work in pairs and trace out in succession the vascular, the digestive, and the nervous systems.

1. For dissection use adult, live animals not over 10 to 12 inches across the carapace. The larger ones have a very strong exoskeleton to cut through. Place the animal on its back. Cut off the legs leaving the coxal joint attached to the body. Cut around the carapace as shown by the dotted line in Fig. 2. Use a heavy knife, such as a well-worn oyster knife. Begin at the point marked "1" and keep well in from the edge to avoid the strong trabeculæ which pass dorso-ventrally along the border. Then go back to the abdomen and make the cuts marked "2" and "3." After this cut through the interarticular membrane on the dorsal side of the caudal spine.

The spine and ventral piece of exoskeleton may then be lifted up from the dorsal carapace and the cuts "2" and "3" carried

forward allowing the knife to follow the path of least resistance. Do not cut too far from the median line on account of the trabeculæ. Finally separate the ventral leaf with the viscera attached from the dorsal leaf of the exoskeleton which may be thrown away. Use the hand to make the separation. Cut the muscles

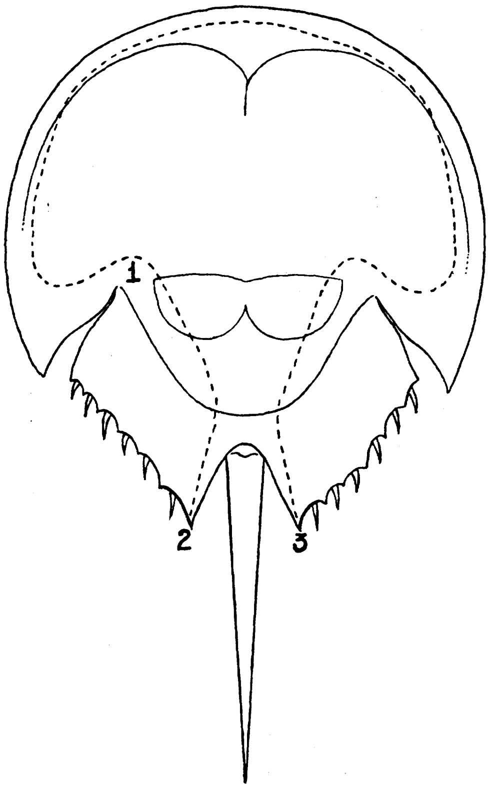

FIG. 2. Diagram of ventral view of *Limulus,* showing location of line of primary incision.

where necessary with a scalpel but take due care not to injure the pericardium and heart lying along the mid-line. Finally lift out the whole of the visceral mass and place, dorsal side up, in a deep crystallization dish. Continue the dissection under sea water.

2. The mush which covers the lateral parts of the animal is composed of gonad (orange) and liver (yellowish-green).

3. The heart[1] and its vessels are more or less exposed when the carapace is removed. Carefully free the pericardial area from gonad, etc., preserving if possible the frontal artery, the aortic arches, and the lateral arteries. In some cases the collateral arteries and their fusion to form the superior abdominal artery can be seen. Some of the branchio-cardia canals, which return blood from the gills to the pericardium, can also be identified. Note also the median cardiac nerve and make out as much as possible of the heart itself and its eight pairs of ostia. Then have your dissection demonstrated by an instructor. (The vascular system is not well shown in such fresh material, but the main features can usually be indicated.)

4. Remove the heart exposing the digestive system. Clear up the neighborhood in the same way as for the vascular system. Take care to preserve the large ducts by which the liver communicates with the intestine. The digestive system is a very simple one and will require little or no demonstration by the instructors.

5. Cut the digestive tract near the posterior end and reflect it forward. This exposes the cartilaginous endocranium. The central nervous system lies directly beneath the endocranium, which must first be removed in order to expose the nerve ring. This can best be done by cutting along the median line of the cartilage with scissors, beginning at the anterior end and taking great care not to damage the tissues beneath. Reflect the halves of the endocranium laterally. This exposes the nerve ring and ventral nerve cord. Carefully clear up the area; work the nerves free with fine curved forceps or needles. Take great care to damage the nervous structures themselves as little as possible. Finally work back along the ventral nerve cord and expose the five ganglia; do not lift the cord as the nerves radiating from the ventral surface of the ganglion will thus be completely destroyed. Special

[1] The circulatory system of young specimens (carapace of three inches) may be injected through the heart by inserting the needle in the median line in the groove between the carapace and abdomen. The entire circulatory system may be followed by removing the dorsal part of the carapace, since the injected vessels may be readily seen through the semi-transparent ventral body wall. Larger specimens may be similarly injected with some advantage in dissecting.

care should be taken in clearing up the area just anterior to the forebrain. Otherwise the delicate olfactory nerves and the nerves to the eyes will be entirely destroyed. Similar care should be taken to preserve the long and delicate nerves which pass from the posterior border of the main nerve ring to the chilaria and operculum.

The nerves arise from the central nervous system in groups of two; one dorsal, called the hæmal, and one ventral, the neural From the nerve ring, eight pairs originate; six large anterior ones and two smaller posterior ones. In addition a median and two lateral olfactory nerves; a median and two lateral eye nerves, arise from the front of the ring. Great care must be used in finding them. The ventral nerve cord has five ganglia with pairs of hæmal and neural nerves from each. The last three sets of nerves join the posterior end of the cord. Find as many of the nerves as you can. An instructor will demonstrate and complete the dissection where possible.

6. Study the arrangement of the coxal glands, the brick-red tubes which lie lateral to the nerve ring. This is the excretory system.

In the absence of an instructor the following papers will be of assistance:

Lankester, E. Ray. Is *Limulus* an Arachnid? Quart. Journ. Micr. Sci., 21, N. S., 1881.

Placed *Limulus* with the Arachnida.

Patten and Redenbaugh. Studies on *Limulus,* I. The Endocranium of *Limulus, Apus* and *Mygale*. Jour. Morph., 16, 1899. Studies on *Limulus,* II. The Nervous System of *Limulus* with Observations upon the General Anatomy. Jour. Morph., 16, 1899.

Morphological account; good figures; direct aid in dissection.

Patten and Hazen. Development of the Coxal Glands, Branchial Cartilage and Genital Ducts of *Limulus polyphemus*. Jour. Morph., 16, 1900.

Patten, Wm. The Evolution of Vertebrates and their Kin. Blakiston, Phila., 1912.

Complete bibliography.

VII.

Table III.

Class List as Posted on the Afternoon of August 8, 1920, on Returning from a Collecting Trip to the North Falmouth Flats.

(Collecting from 3:20 to 6:00; low tide 5:00.)

Porifera
Cliona
Microcione
Tethya

Cœlenterata
Edwardsia
Eloactis
Hydractinia
Pennaria
Podocoryne
Obelia commissuralis
Sagartia leucolena
luciæ
modesta
Sertularia
Eudendrium album

Platyhelminthes
Cerebratulus
Lineus
Micrura
Stylochus
Syncœlidium

Nemathelminthes
Pontonema

Echinoderma
Autolytus
Arabella
Arenicola
Cirratulus
Clymenella
Diopatra
Enoplobranchus
Glycera sp.
Harmothoe
Hydroides
Lepidonotus
Lumbrineres tenuis
Nereis limbata
virens
Pectinaria
Phascolosoma
Phyllodoce
Pista
Platynereis
Podarka
Polycirrus
Sabella
Sabellaria
Scoloplos acutus
fragilis
robustus
Spirorbis
Sthenelais
Maldane

Bryozoa
Ætea
Bugula
Crisia
Flustrella
Lepralia
Membranipora
Schizoporella

Arthropoda
Amphithoe
Balanus
Callinectes
Caprella
Carcinides
Chiridotea
Crangon
Gammarus
Heteromysis
Idothea baltica
metallica
Libinia dubia
emarginata
Limulus
Pagurus pollicaris
longicarpus
Palæmonetes
Panopeus
Pinnixa
Orchestia
Talorchestia
Ovalipes
Uca
Virbius
Hausterius
Jæra
Ericksonella

Mollusca
Chætopleura

Pelecypoda
Anomia
Cumingia
Ensis
Lævicardium
Macoma
Mactra
Modiolus demissus
modiolus
Mytilus
Nucula
Pecten
Petricola
Solemya
Tellina
Teredo
Venus
Mya
Ostræa

Gasteropoda
Acmea
Bittium
Busycon
Columbella avara
lunata
Crepidula convexa
fornicata
plana
Lacuna
Littorina litorea
palliata
rudis
Nassa obsoleta
trivittata
Natica duplicata
heros
Odostomia
Urosalpinx

Chordata
Amarœcium
Botryllus
Dolichoglossus
Molgula
Perophora
Styela

126 species